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ABSTRACT

This study analyzed wrist, elbow, and hip actions of golfers who were accurately driving a golf ball a maximum distance. Electrogoniometry and cinematography were used to measure wrist, forearm, elbow, and hip actions during the downswing of 10 low-handicap golfers who were attempting to drive a minimum of 225 yards within a 50-yard corridor. Elgons were used to measure movements of the elbow (flexion-extension), forearm (pronation-supination), and wrist (Adduction-abduction, flexion-extension) at selected angles of the arm relative to a vertical line passing through the shoulder. Lateral and horizontal hip movements were recorded with a specially constructed analyzer. Motion pictures (64 frames/second) were taken in order to measure shoulder joint positions. Electrogoniograms were analyzed at selected positions: top of backswing; at the position in the downswing where the left arm was horizontal, 45 degrees from vertical, 22.5 degrees from vertical, and vertical; and at the position in the downswing when the ball was contacted. It was concluded that there was no common pattern of action among the low-handicap golfers, but that there were certain common characteristics relative to the timing and sequence of specific actions. (Author/JB)

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THE SEQUENCE OF HIP AND SELECTED UPPER-EXTREMITY JOINT MOVEMENTS DURING THE GOLF DRIVE

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of the Requirements for the Degree
Doctor of Physical Education

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by
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ABSTRACT

THE SEQUENCE OF HIP AND SELECTED UPPER-EXTREMITY JOINT MOVEMENTS DURING THE GOLF DRIVE

Purpose of the Study

The purpose of this study was to analyze, using electrogoniometry and cinematography, the wrist, forearm, elbow, and hip actions of low-handicap golfers while they attempted to accurately drive for maximum distance, The analysis was made at six points in the swing, which were as follows:

1. At the top of the backswing.
2. At the position in the downswing where the left arm was horizontal.
3. At the position in the downswing where the angle formed by the left arm and a vertical line drawn through the acromion process was forty-five degrees.
4. At the position in the downswing where the angle formed by the left arm and a vertical line drawn through the acromion process was twenty-two and one-half degrees.
5. At the position in the downswing where the long axis of the left arm was vertical.
6. At the position in the downswing when the ball was contacted.

It was hypothesized that a common pattern of movement of both extremities and the hips of all golfers throughout the downswing could be identified.

Methods and Procedures

Ten subjects, five from Western New England and five from Northern New York, participated in the study. Club professionals and golf coaches were asked to identify potential subjects. Those golfers receiving unanimous recommendations were selected as subjects.

Elgons were attached to the upper extremities of the subjects to record the joint action at both elbows, both forearms and both wrists. Two elgons were used at each wrist to record both flexion-extension and abduction-adduction movements. The elgons used to measure elbow action were similar to those used in previous studies by other investigators. The elgons used to measure forearm action and wrist flexion and extension as well as wrist abduction and adduction were especially adapted for this study. A wrist bracelet was developed to hold the wrist portions of the respective elgons in place. A hip analyzer was also developed in order to ascertain the position and movement of the hips throughout the swing.

Electrical impulses from the elgons were channelled through two electrogoniometer control panels and recordings (goniograms) made on light-sensitive paper by using three Honeywell Visicorders. The control panels were used to calibrate the electrical impulses from the elgons by use of a special protractor so that visicorder tracings could later be converted into the degrees of joint movement.

Two sites were used for testing, one in Northern New York and one in Western Massachusetts. Both sites had a large, flat, grassed area referred to as the "tee area". Each site also had a target zone that was fifty yards square at a distance of 225 yards from the tee area. There were no obstructions between the tee and the target.

A sixteen millimeter motion picture camera, which was operated at sixty-four frames per second, was mounted on an adjustable tripod sixteen feet in front of the performing subject. The camera was adjusted so that the center of the exposed frame of film was at the subjects's shoulder height. Motion pictures taken of each subjects's trial were used to determine the six reference points of the left arm movements which were selected for analysis.

The exact moment of ball contact of each trial was recorded on the goniograms by use of an electrical circuit through two contacts between the ball and the tee upon

which the ball rested. When the ball was struck the circuit was broken and this was registered on each goniogram. The face of an electric timer, which was started by the tester and automatically stopped at ball contact, was within the framing of the motion picture camera and used to synchronize the data from the goniograms and the motion picture film.

Subjects performed repeated tests until each subject had successfully driven six shots into the target zone. This procedure was repeated during a second testing trial so that all subjects performed twelve successful drives.

An enlarger was adapted to facilitate viewing of single frames of the motion picture film. This process allowed the investigator to record the exact readings of the electric timing device and the angular position of the subject's left arm. By measuring the angle differences and the time differences between adjacent frames, it was possible to assign a given time to each of the selected left arm positions in the swing. This information was used with the time lines on the goniograms to determine the exact moment when the joint angles should be measured to correspond with the reference points selected for analysis. By doing this, it was possible to obtain the angle reading for each joint at each of the selected reference points.

Results

An analysis of the literature on golf revealed a consensus on the sequence of actions necessary for driving a golf ball a long distance. This summation of acts is referred to as a "model swing". The joint angles and changes in them were used to determine to what extent the subject's performance agreed with the consensus from the literature. The following information is a resume of the findings.

In determining the left arm positions as the selected reference points, the measurements were made of the angle between the long axis of the left arm and a vertical line passing through the acromion process of the left shoulder. The mean angle of the left arm at the top of the backswing was 137.6

degrees, but there was considerable variability among subjects. The standard deviation was 28.1 degrees, and the range of the ten scores was from 89.7 degrees to 190.8 degrees.

At ball contact the average angle of the left arm position of all ten subjects was minus 9,1 degrees indicating that it had passed the vertical position at this point. All subjects, except one, contacted the ball after the left arm passed the vertical position. The tenth subject made contact at .3 degrees. The values ranged from .3 degrees to minus 23.8 degrees. The standard deviation was 7.5 degrees.

The recordings indicated that all subjects followed a similar pattern of movement of the right elbow (see Figure 1, page 11). At the top of the backswing, the right elbow was held at a mean position of 112.2 degrees. The recordings ranged from 96.2 degrees to 121.0 degrees with a standard deviation of 6.61 degrees. At ball contact, the mean position of the right elbow was 149.6 degrees. The standard deviation was 10.35 degrees, and the range of the measurements from the top of the backswing to ball contact was 37.4 degrees. It was significant that 14.1 degrees of this amplitude was registered between the twenty-two and one-half and the vertical reference positions.

The findings for right forearm rotation revealed an average fluctuation of only 3.5 degrees throughout the downswing (see Figure 2, page 12). Again the major portion of this action occurred between the twenty-two and one-half degree and vertical left arm positions. It was also significant to note that there was a large amount of variability among the subjects, as indicated by standard deviations ranging from 20.1 degrees to 23.0 degrees at the various reference points.

At the top of the backswing, the right wrist was hyperextended to a mean angle of 206 degrees (see Figure 3, page 13). The average amplitude of the flexion movement of the right wrist during the downswing was 22.3 degrees: 10.2 degrees of this occurred between the twenty-two and one-half degree and vertical positions of the left arm and 12.8 degrees between

the vertical position and the moment of ball contact. The mean wrist position at ball contact was 179.7 degrees, a value indicating almost complete extension.

A mean value of 200.3 degrees lateral deviation was recorded for the right wrist position at the top of the backswing indicating an abducted position (see Figure 4, page 14). There was a rather constant rate of adduction throughout the swing with the mean position for all subjects attained at ball contact reaching 173.3 degrees.

The mean angulation of the left elbow at the top of the backswing was 171.6 degrees (see Figure 5, page 15). At ball contact, it was 176.5 degrees showing a mean amplitude of movement of 4.9 degrees throughout the downswing. One subject registered the greatest amount of flexion, 152 degrees, at the top of the backswing and neared full extension, 179 degrees, at ball contact.

There was very little change of position in left forearm rotation from the top of the backswing, where a mean position of 84.2 degrees was attained, to the twenty-two and one-half degree position of the left arm (see Figure 6, page 16). From this point on all subjects pronated extensively, one subject registering 31.5 degrees of movement. All subjects continued to pronate the left arm while it moved beyond the vertical position through to ball contact.

There was considerable variability in the angles measured for both the flexion-extension and abduction-adduction movements of the left wrist (see Figures 7 and 8, pages 17 & 18). At the peak of the backswing, the mean value for flexion-extension movement was 187.7 degrees, which shows slight hyperextension. The standard deviation was 25.8 degrees. The values ranged from 131.5 degrees to 221.7 degrees. The mean position at ball contact was 167.8 degrees indicating slight flexion. Between the twenty-two and one-half degree vertical positions of the left arm, however, four subjects extended their left wrists while six subjects flexed them. Most of the action of the left wrist took place after the

left arm had passed the forty-five degree reference position.

The mean angle for the left wrist was 208.4 degrees indicating considerable abduction at the peak of the backswing. There was little variability and all subjects followed a similar pattern of movement. The mean value for the total amount of adduction when the left arm was moved from the peak of the backswing to ball contact was 33.3 degrees The major portion of this action occurred in the last part of the swing. From the left arm position of twenty-two and one-half degrees to vertical, there were 13.1 degrees of adduction, from the vertical left arm position to ball contact 10.3 degrees.

The hip movements of the subjects varied. In this study, only those movements that were made in a horizontal plane passing through the hips were measured. Some subjects raised or dipped their hips during parts of the swing. Such actions were not recorded.

The hip analyzer was affixed to the posterior aspects of the pelvis by means of a belt that encircled the hips. The recordings of hip action were representative of two things; a positioning of a midpoint of the posterior portion of the perimeter around the hips and the angle formed in a horizontal plane between an imaginary line crossing the superior iliac crests and intended line of flight of the golf drive. The movements measured are referred to as lateral sliding of the hips and horizontal turning of the hips.

The use of the feet and their role in the golf swing was not part of this study. However, it was important to have a general understanding of the positioning of the feet because this could possibly affect other body actions. The manner in which each subject positioned his feet for each shot was recorded through the motion picture filming. These tracings were collectively studied and the following generalizations were made; six subjects used an even stance. three subjects used a closed stance and one subject used an open stance. Seven of the ten subjects toed out with the left

foot while the other three subjects held it square. Six subjects toed out with the right foot and the other four held the left foot square. Eight subjects had their heels on a line parallel to the line of flight.

Five of the nine subjects demonstrated greater lateral sliding between the ninety degree and the forty-five degree positions of the left arm than between any other two adjacent reference positions (see Table 1, page 19). These five subjects registered an average of 40 percent of their total hip movement between these two reference points. The mean amount of lateral sliding for all subjects from the peak of the backswings through to ball contact was 11 inches. There was considerable variability as indicated with a standard deviation of 3.21 inches. The range of movement was from 14.7 inches to 4.1 inches.

The greatest amounts of hip turn, 13.1 degrees, and lateral sliding, 3.9 inches, were recorded between the horizontal and forty-five degree reference positions. However, values of 11.4 degrees of hip turn between the forty-five and twenty-two and one-half degree left arm positions and 12.8 degrees between the twenty-two and one-half and vertical positions were not greatly dissimilar (see Table 2, page 20). High correlations were found between the amount of lateral sliding and the amount of horizontal turning of the hips. The mean position of the hips at the peak of the backswing was 30.9 degrees (clockwise movement), while the position at contact was minus 13.2 degrees (counterclockwise movement). There was a mean amplitude of 44 degrees.

High values for computed standard deviations indicated considerable variability among subjects relative to hip action.

Conclusions

The findings in this study indicate that general patterns of movement throughout the golf swing vary among subjects. Therefore, the hypothesis that there is a specific pattern of of motion, that is, a model swing which is applicable to all

performers is not supported. The findings do indicate that certain body movements are performed by all low handicap golfers but that these movements are not necessarily completed in the same sequence by all golfers when performing the total act. Conclusions relative to such findings are as follows:

1. The standard deviations for the movements of each subject on repeated trials were low. It is concluded that a low handicap golfer has little variability in the movement pattern by which he executes successive golf drives.

2. All subjects demonstrated extensive adduction of both wrists and flexion of the right wrist just before ball contact. These findings support the "delay hit" concept reported in the literature.

3. The findings reveal a high correlation between lateral sliding and horizontal turning of the hips. Furthermore, the hip movements began with the initiation of the downswing and continued through ball contact with no appreciable differences in the amount of movement at the various reference positions. It is therefore concluded that combined hip movements performed at a constant rate throughout the swing are characteristic of low handicap golfers. However, the timing of hip movement was individualistic.

4. The findings revealed a high variability among the subjects in the amount they circumducted their left arm in a clockwise fashion ("peaked to a backswing"). It is therefore concluded that low-handicap golfers have considerable variability in the amount of backswing taken prior to the downswing.

5. The conclusions reached relative to specific body actions during the downswing are as follows·

   a. The left elbow is near full extension at ball contact.

   b. At the moment of ball contact, the left elbow

is extended to a greater degree than the right elbow.

c. There is a great deal of variability among golfers in the amount of rotation of the forearms during the golf swing

d. There is a great deal of variability in the flexion-extension positioning of the left wrist during the downswing; however, there is less variability among golfers at ball contact. At this point, the left wrist is near full extension.

e. When ball contact is made, the long axis of the left arm is slightly beyond the vertical position.

f. Low-handicap golfers assume a variety of positions while addressing the ball for the drive in golf.

Implications

The findings in this study suggest several implications concerning the execution of the golf swing. Although it is concluded that there is no "model swing" for all golfers, it is implied that of the body motions studied, certain of them are essential to a successful golf drive. Therefore, teachers and players should be aware of them. Those movements or positionings are:

1. The left arm is near full extension at ball contact.

2. Both wrists are brought to full extension and neutral between adduction and abduction at ball contact.

3. The major portion of right elbow extension occurs after the left arm has reached the 22.5 degree reference position and continues through ball contact.

4. At the moment of ball contact the left elbow is extended more than the right.

5. The function of both forearms is individualistic and probably dependent upon other variables such as grip, stance and stature.

6. The major portion of wrist action (adduction of both wrists and flexion of the right wrist) occurs after the

left arm has reached the 22.5 degree reference position and continues through ball contact.

Recommendations

1. It is recommended that the technique and instrumentation used in this study be employed to investigate the same body actions:
   a. at selected reference points during other shots in golf.
   b. of different caliber players.
   c. of low-handicap players grouped according to physical size.
2. It is recommended that a more complete analysis of the same joint actions studied be conducted after the left arm passes the twenty-two and one-half degree position. This analysis should include measures of linear velocity in order to more completely understand the summation of forces.
3. It is recommended that the effects of the manner of hand positioning (grip) upon the actions of the elbows and wrists be analyzed. Some of the instrumentation and technique used in this study could be employed.
4. It is recommended that a study be conducted to determine the effects of different stances upon the actions of the elbows, wrists and hips.
5. It is recommended that the technique and instrumentation developed in this study to determine wrist action be used in the analysis of other athletic activities.
6. It is recommended that the hip analyzer be used in the analysis of hip action in other types of athletic performance.

Figure 1

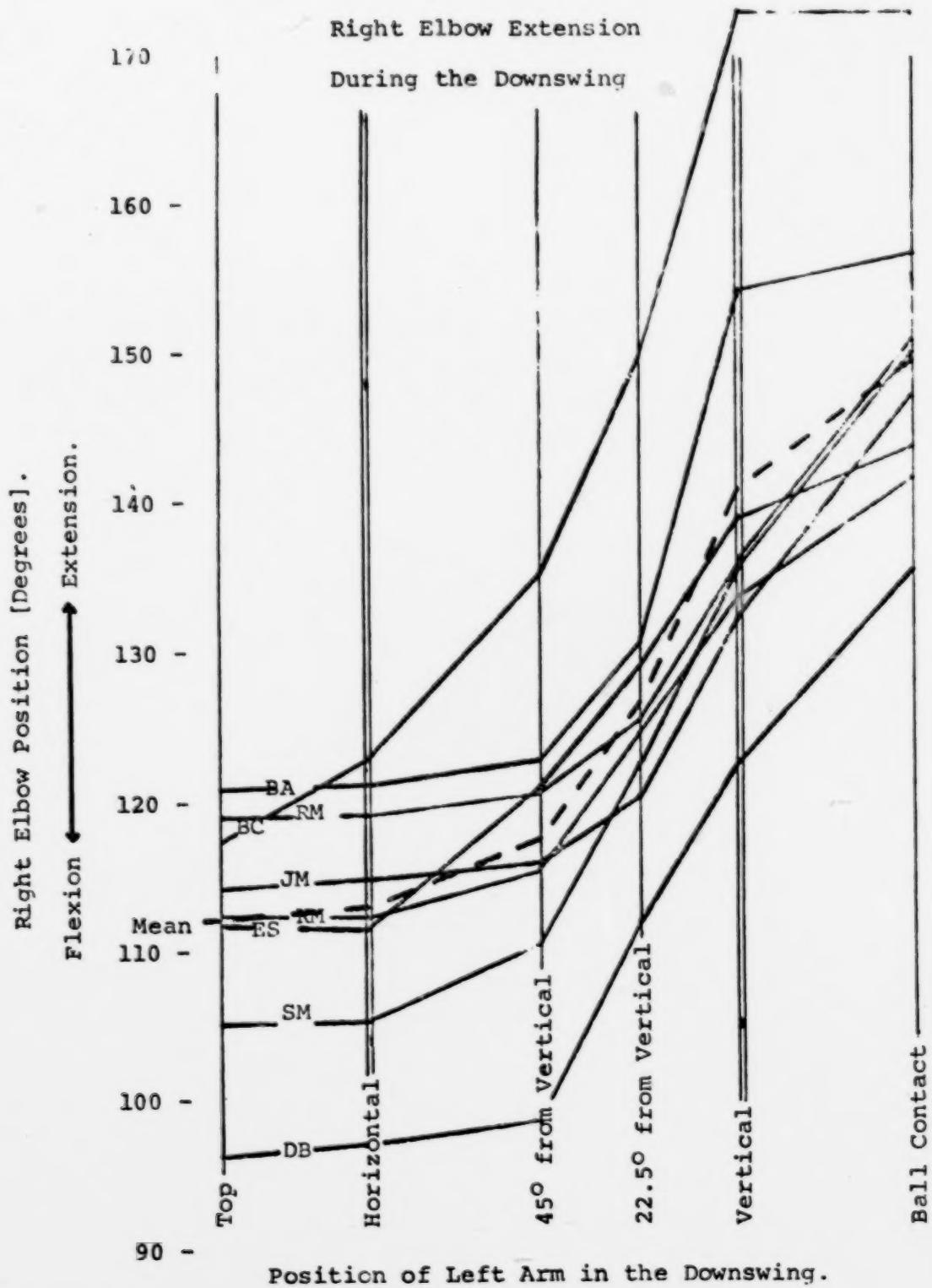

Right Elbow Extension
During the Downswing
170
160 -
150 -
140 -
130 -
120 -
Mean
110 -
100 -
90 -
Right Elbow Position [Degrees].
Flexion
Extension.
BA
RM
BC
JM
TM
ES
SM
DB
Top
Horizontal
45° from Vertical
22.5° from Vertical
Vertical
Ball Contact
Position of Left Arm in the Downswing.

Figure 2

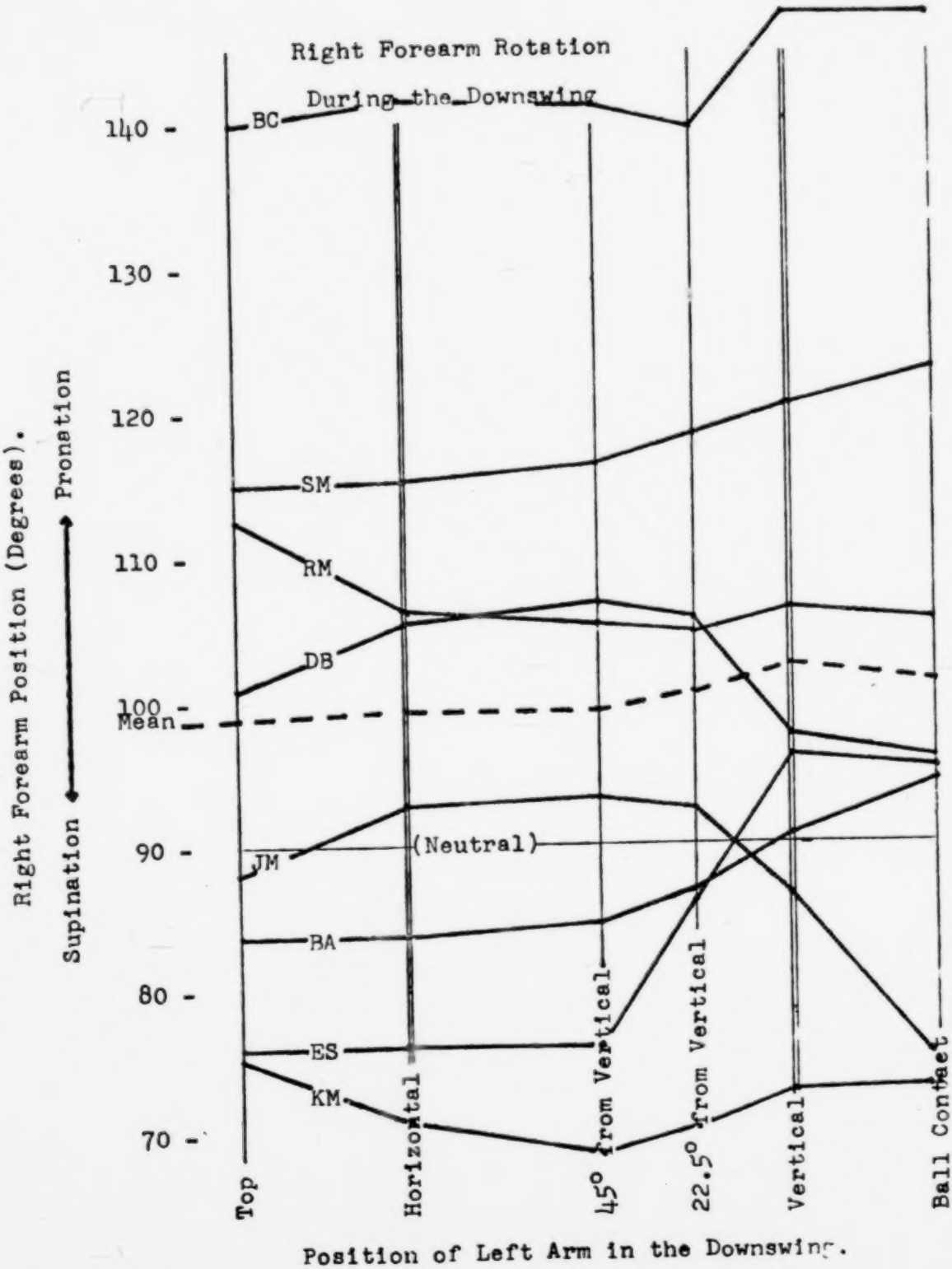

Right Forearm Rotation
During the Downswing
Right Forearm Position (Degrees).
Supination
Pronation
140 -
130 -
120 -
110 -
100 -
90 -
80 -
70 -
Mean
(Neutral)
BC
SM
RM
DB
JM
BA
ES
KM
Top
Horizontal
45° from Vertical
22.5° from Vertical
Vertical
Ball Contact
Position of Left Arm in the Downswing.

Figure 3

Right Wrist Flexion and Extension

During the Downswing

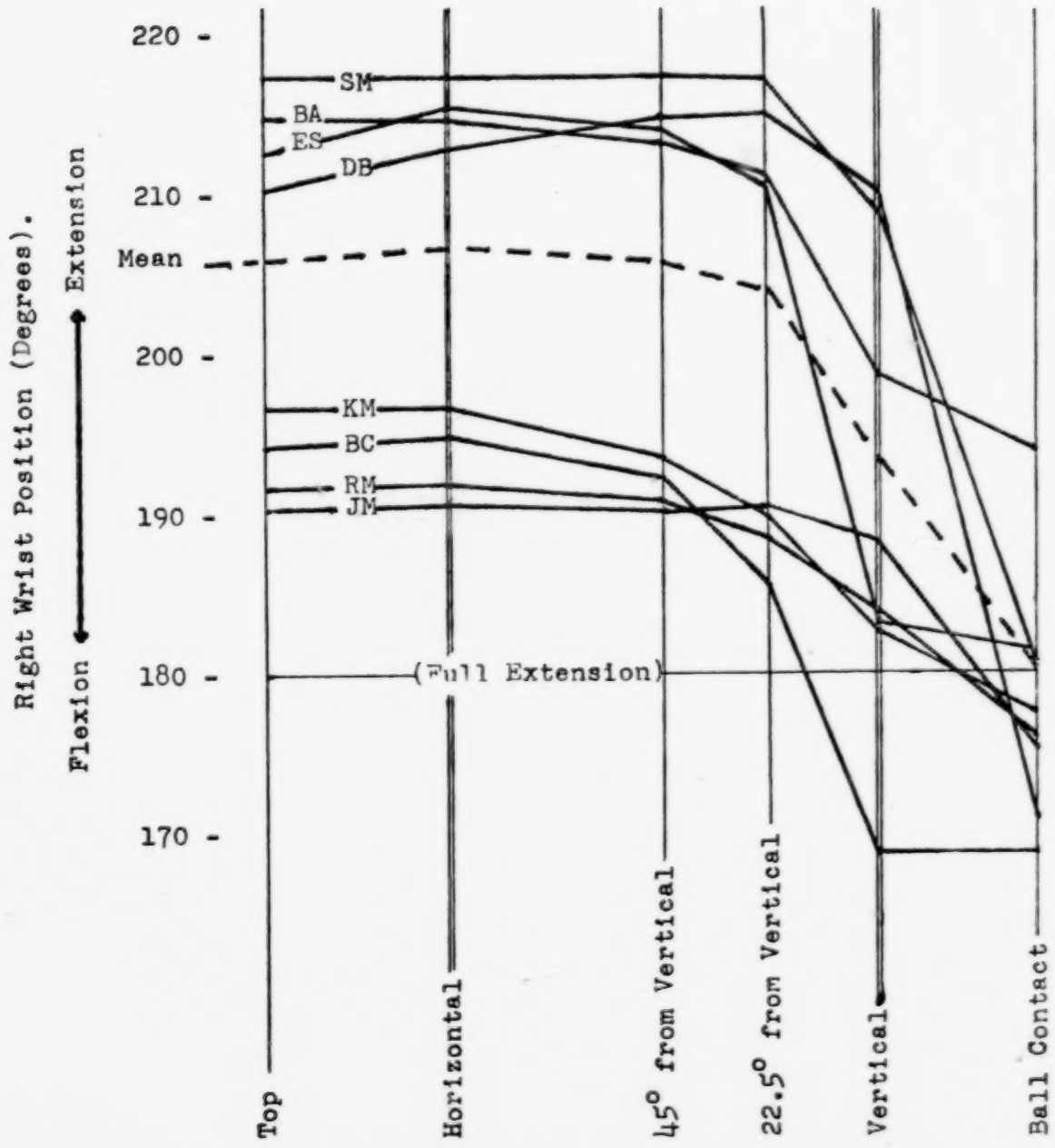
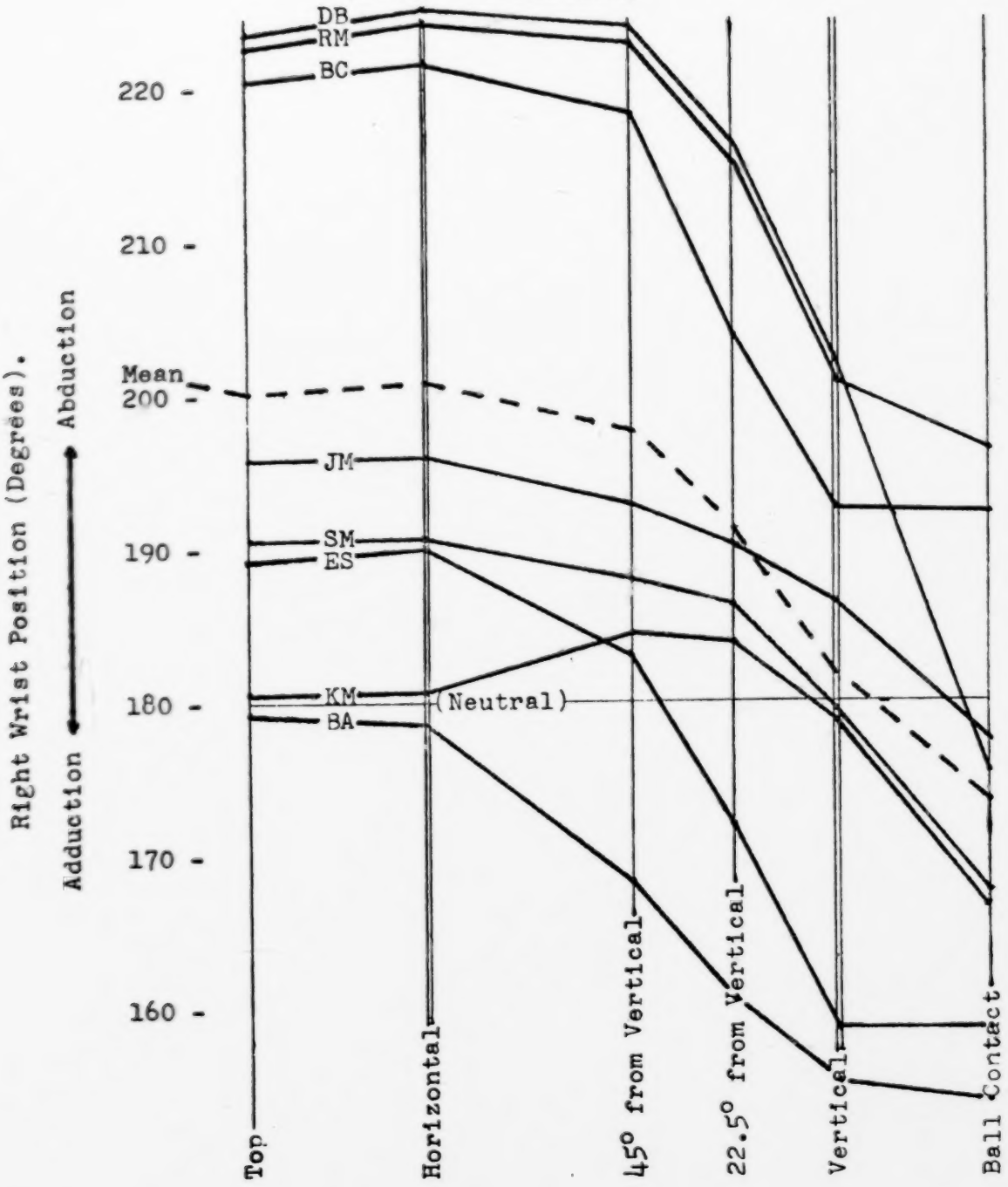


Figure 4

Right Wrist Abduction and Adduction

During the Downswing



Position of Left Arm in the Downswing.

Figure 5

Left Elbow Action
During the Downswing

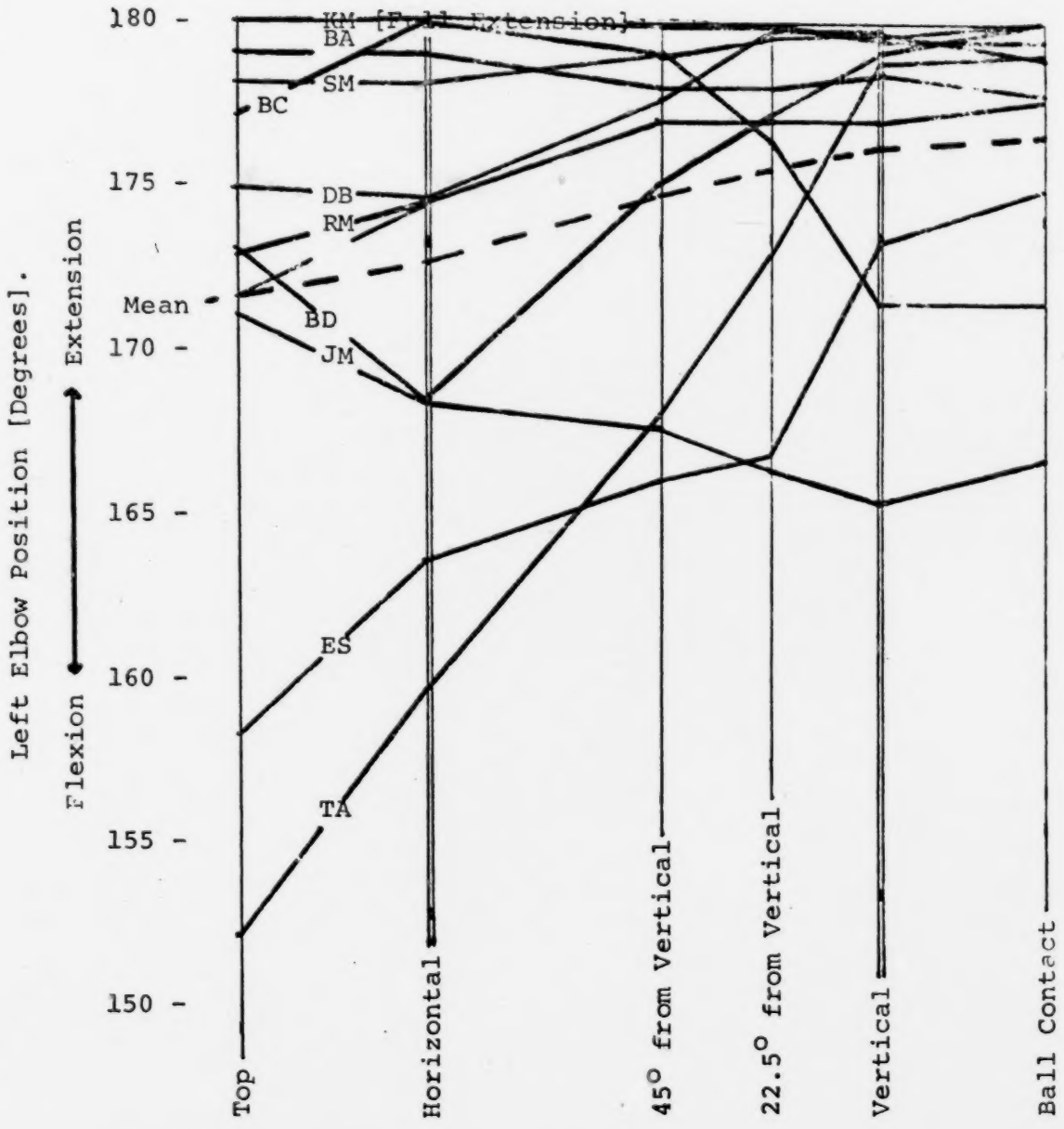
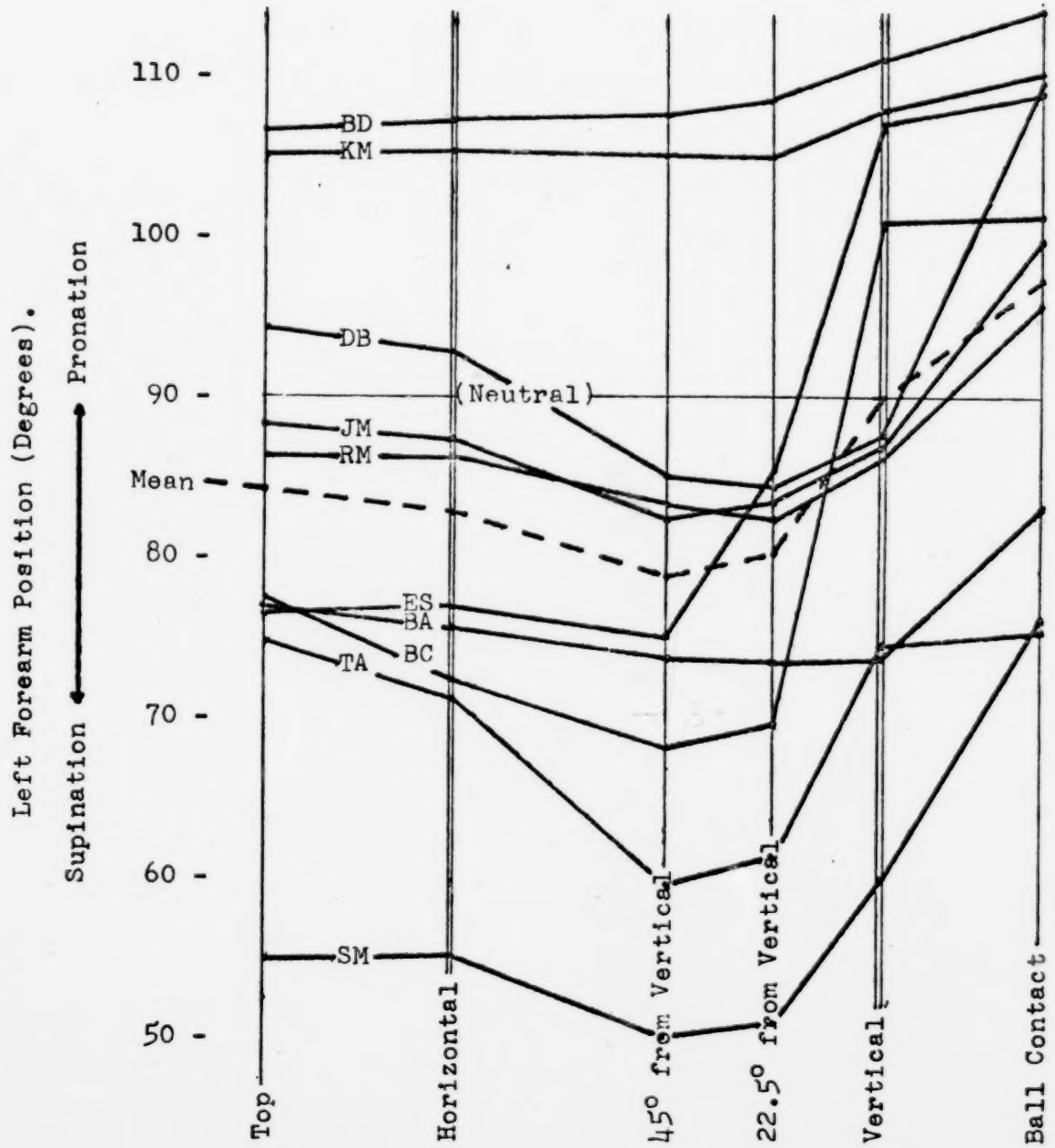


Figure 6

Left Forearm Rotation

During the Downswing

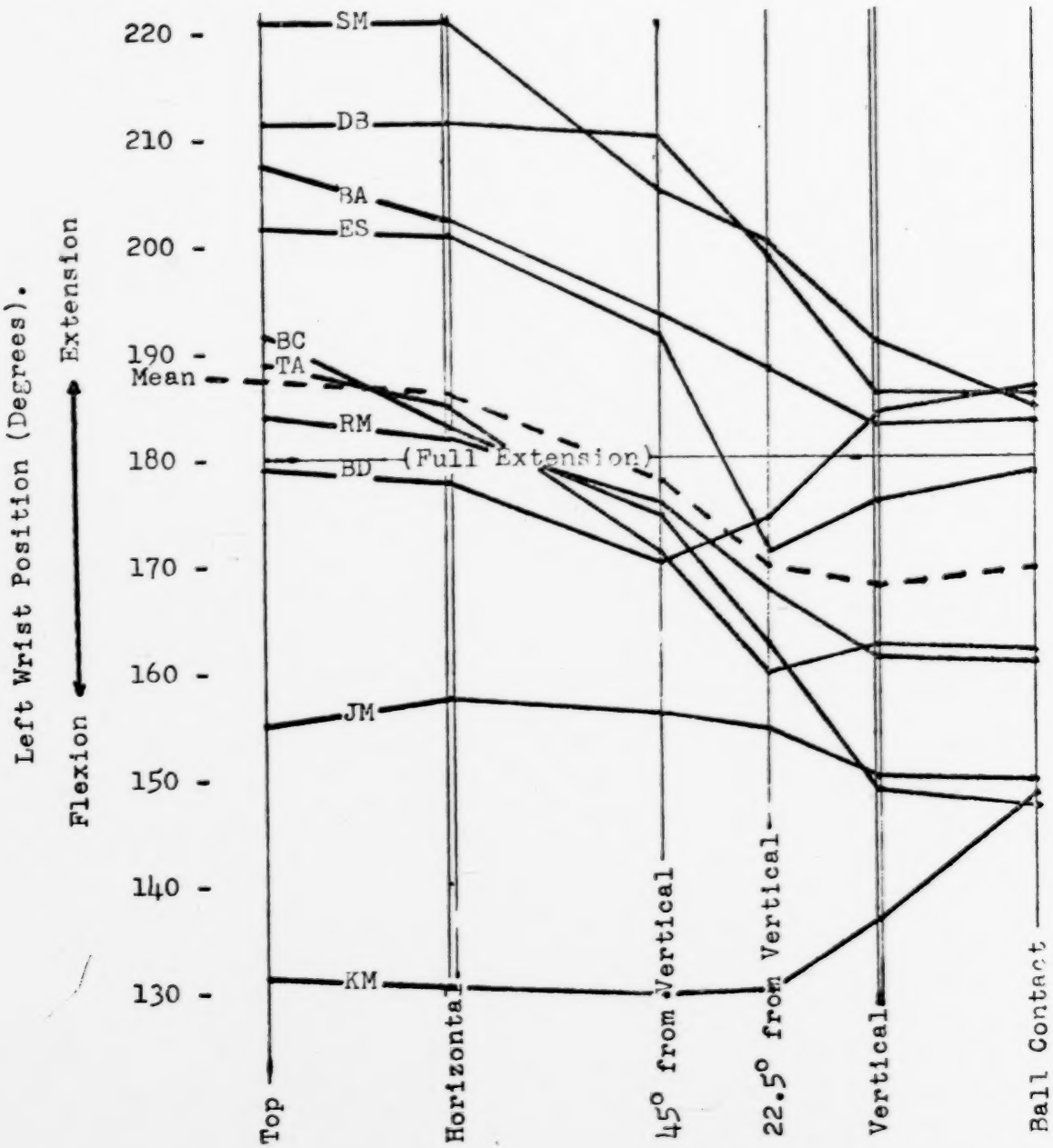


Position of Left Arm in the Downswing.

Figure 7

Left Wrist Flexion and Extension

During the Downswing

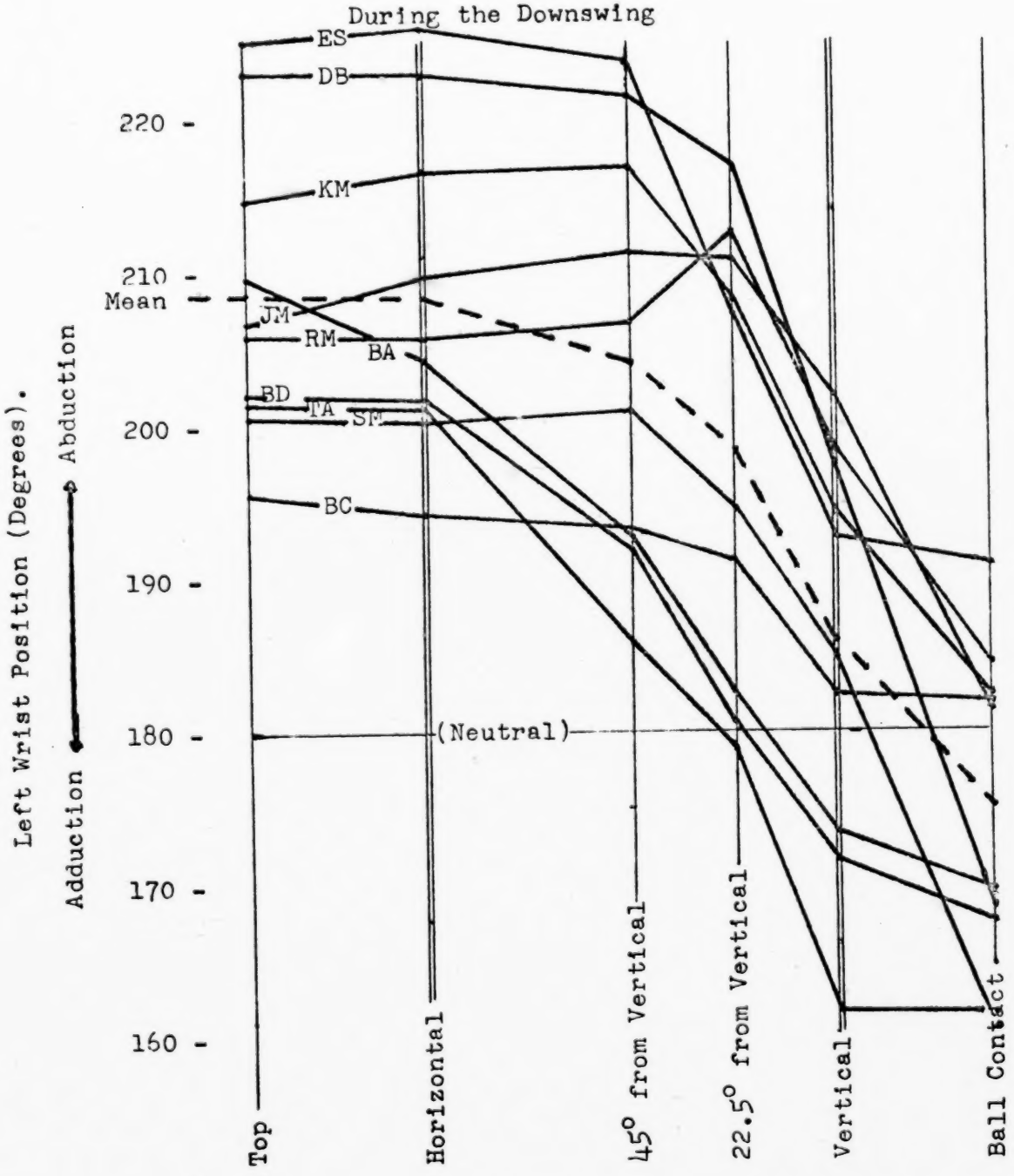


Position of Left Arm in the Downswing.

Figure 8

Left Wrist Abduction and Adduction

During the Downswing



Position of Left Arm in the Downswing.

TABLE 1

Lateral Sliding of Hips in Inches

Subject	Total Forward Motion	Interval between reference points of downswing: Top and Horizontal	Horizontal and 45°	45° and 22.5°	22.5° and Vertical	Vertical and Ball Contact
BA	13.0	.9*[1]	5.0[2]	3.8	3.0	1.4
TA	13.6	1.0*	5.3	4.1	2.9	
BC	7.4	.8*	1.8	2.4	3.9	
BD	14.7	2.3*	6.9	3.4	2.7	.8
JM	12.1	1.6	3.6	2.4	2.4	2.7
RM	12.3	.9	5.0	2.5	3.3	2.4
RM	9.5	2.0*	2.3	2.4	4.1	3.0
SM	13.6	3.7	3.5	4.6	2.9	
ES	4.1	2.0*	1.6*	1.7	3.1	
Mean	11.0	1.7	3.9	3.0	3.1	2.1
Standard Deviation	3.21	.89	1.70	.92	.52	.83
Range	14.7 to 4.1	3.7 to .9	6.9 to 1.6	4.6 to 1.7	4.1 to 2.4	3.0 to .8

[1](*) Hips moved in a reverse direction (right).

[2](-) Indicates movement of greatest length.

TABLE 2

Amplitudes of
Horizontal Turning of Hips in Degrees

Subject	Stance	Backswing	Contact	Between Reference Points: Top to Horizontal	Horizontal to 45°	45° to 22.5°	22.5° to Vertical	Vertical to Ball Contact	Total 1 to 5 or 6
BA	7.6[1]	39.5	-17.9	4.7	19.73[3]	14.8	12.0	6.2	57.4
TA	13.3	29.4	-21.8	1.9	19.2	15.3	14.3		51.3
DC	- .8[2]	26.6	- .8	-.2	4.3	8.3	15.3		27.2
BD	18.2	42.7	-14.8	5.3	23.4	13.0	11.6	4.3	57.5
JM	.3	38.0	- 7.8	6.1	14.3	8.3	7.9	8.7	45.8
KM	-16.2	20.7	-32.8	3.5	18.8	11.3	12.5	6.8	53.0
RM	1.2	24.5	-11.2	-5.2	7.0	8.7	15.0	10.2	35.7
SM	-4.7	44.8	-11.3	12.7	12.8	16.9	13.7		56.0
ES	5.5	11.7	- .7	-4.7	-1.2	5.8	12.8		12.3
MEAN	2.7	30.9	-13.2	2.7	13.1	11.4	12.8	7.2	44.0
S.D.	9.53	10.50	9.60	5.3	7.75	3.61	2.12	2.04	14.91
RANGE	18.2 to -16.2	44.8 to 11.7	- .7 to -32.8	12.7 to -5.2	23.4 to -1.2	16.9 to 5.8	15.3 to 7.9	10.2 to 4.3	57.5 to 12.3

1 No sign indicates clockwise turning from the line of flight of the ball.

2 (-) Indicates counterclockwise turning from the line of flight of the ball.

3 (_) Indicates movement of greatest amplitude.